Leading Indicators of Currency Crises in Ghana

Sigma One Corporation

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Dr. Curtis Youngblood
Sigma One Corporation

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LEADING INDICATORS OF CURRENCY CRISES IN GHANA

This note develops a set of leading indicators of currency crises for Ghana and uses it to see how useful it might have been in predicting the currency crisis of July 2000. It is based on the work of Eichengreen, Rose, and Wyplosz (1997) and Kaminsky, Lizondo, and Reinhart (1998), who used panel data to study contagion effects and early warning systems, respectively, but differs by applying their methods to a single country. This brief also draws heavily on an earlier piece (Youngblood, 2002), but differs significantly in the period upon which the analysis is based; this in turn results in significant changes in the set of indicators that provide reliable signals of an impending currency crisis with sufficient notice for the authorities to address the problem.

We first describe the index that lets us determine the timing and duration of currency crises. Next we present a set of candidate indicators and assess how well each indicator heralds a currency crisis. We then go back in time to the end of 1998, construct the index and the indicators, update them on a quarterly basis, and see how strongly the indicators were signaling prior to the crisis in July 2000. We find that there were strong and persistent signals of the crisis up to 18 months in advance that got stronger one year in advance of the crisis. We conclude that an early warning system could provide a useful periodic "heads up" to the monetary authorities.

An Index of Exchange Market Pressure

Pressure in the exchange market may be manifested as a tendency for the exchange rate to appreciate or depreciate. But the monetary authorities may choose to resist an incipient depreciation by selling foreign exchange and running down reserves. As Eichengreen, Rose and Wyplosz (1997) point out, interest rate policy can also be used to countervail against pressure on the exchange rate to fall. The index of exchange market pressure combines movements in the nominal exchange rate, gross international reserves (less gold) at the Bank of Ghana, and interest rates on 3-month Treasury bills:

$$EMP_t = \frac{1}{\sigma_E^2}\Delta\%E_t - \frac{1}{\sigma_R^2}\Delta\%R_t + \frac{1}{\sigma_i^2}i_t$$

where EMP_t = value of the exchange market pressure index at time t,

$\Delta\%E_t$ = 12-month percentage change in the nominal exchange rate at time t,

$\Delta\%R_t$ = 12-month percentage change in international reserves,

i_t = annualized interest rate on 91-day Treasury bills issued by the government of Ghana, and

σ_j^2 = the variances of the respective series.

Weighting the components in this way offsets the differences in volatility of the component series and makes the conditional variance of the index with respect to each series equal. We use monthly data from January 1987—August 2002.

The resulting values of the index (**Fig. 1**) have no intuitive meaning, unlike the values of a price index. One can measure the percentage change in the EMP index between two points in time and say that pressure in the exchange market has increased or decreased by this amount, but this does not have the same intuitive meaning as saying that inflation was 5% over a certain period. A price index measures the change in one variable, the "price" of a bundle of goods. The EMP index incorporates changes in 3 different variables, of which two are prices and one is a quantity. Despite the lack of interpretive intuition, the index serves as a useful summary measure for conditions in the exchange market, much as the inflation rate is a useful measure of excess demand conditions in the goods market. We can use extreme positive values of the index to define a crisis in the market for foreign exchange. We define our extreme values as those falling more than 2 standard deviations above the mean of the EMP index.[1]

Based on this definition, we find a currency crisis of 10 months duration, beginning in July 2000 and ending in May 2001. (Despite two dips of the index below the threshold during this period, we treated the entire period as a single crisis.) This coincides with a period in which the newly-elected government of Ghana chose to apply for Highly Indebted Poor Country relief (HIPC) because of unsustainably high debt servicing costs. The unsustainability was manifested in inadequate levels of foreign exchange reserves and the significantly higher cost of acquiring more as a result of the sharp depreciation of the cedi.

We next develop a set of indicators that will reliably signal extreme increases in the EMP index well in advance of these increases. This would give the authorities sufficient time to act to avert the crisis. The next section assesses the quality of a set of indicators.

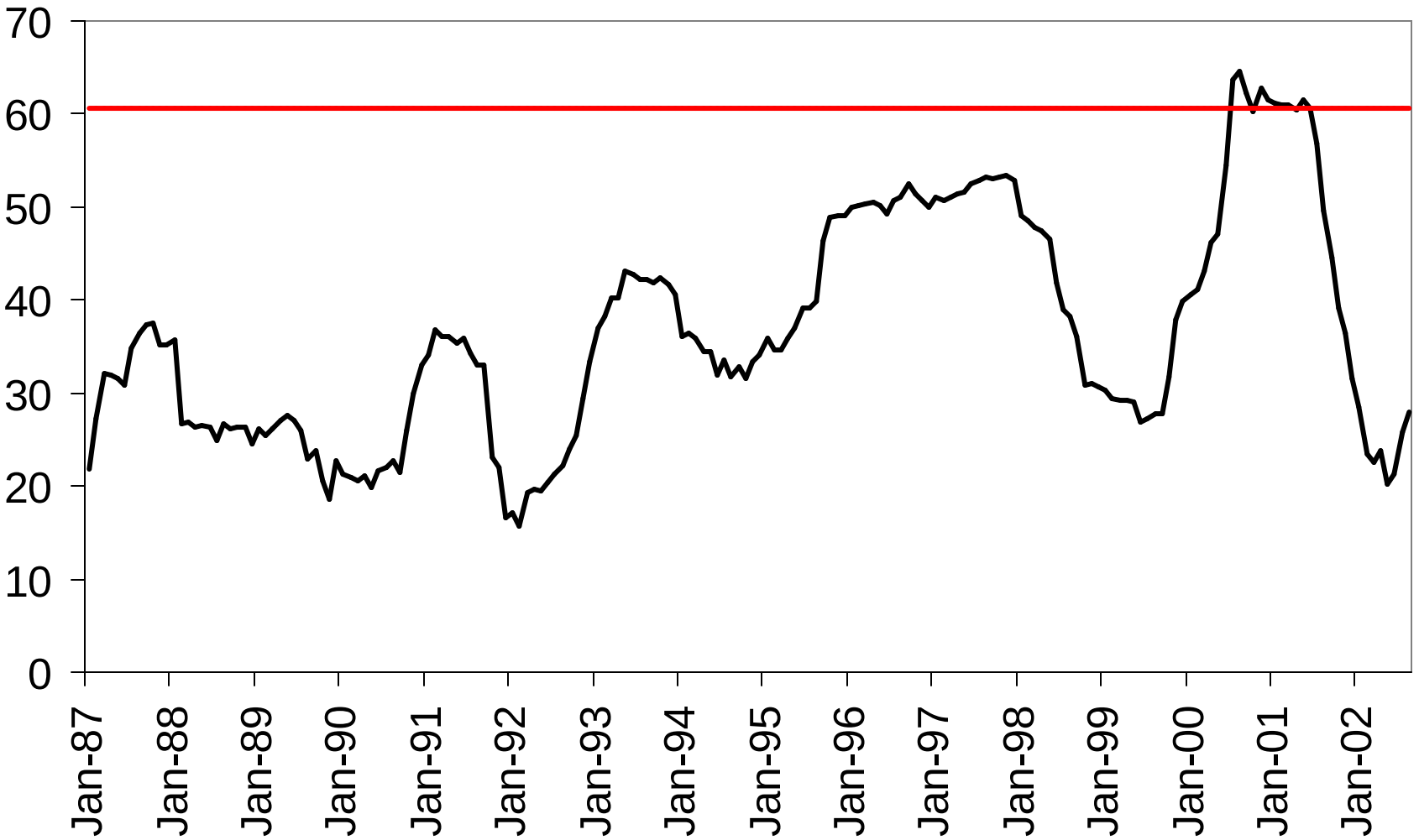
Candidate Set of Leading Indicators

Based on the variables surveyed in Kaminsky, Lizondo, and Reinhart (1998) and on the availability of monthly data from January 1987 through August 2002, we analyzed the suitability of several variables as indicators of impending currency crises.[2] These were the same variables that were assessed in earlier work (Youngblood, 2002). The candidate indicators are presented in Appendix A.

We follow KLR's (1998) method of assessing the validity of the "signals approach". This involves determining if a signal emitted by an indicator is followed by a crisis within 24 months.[3] An indicator emits a signal if the value of the indicator exceeds a threshold, for example, the 90th percentile of the range of values for that indicator.[4] The indicator issues a true signal if a currency crisis follows within 24 months. The indicator generates noise, or a false signal, if it emits a signal but a currency crisis does not occur within 24 months. Based on the

[1] Kaminsky, Lizondo, and Reinhart (1998) apply a stricter criterion of 3 standard deviations, while Eichengreen, Rose and Wyplosz (1997) use a looser standard of 1.5 standard deviations.
[2] Data on monetary aggregates were available through September 2001, so indicators based on these aggregates were only available through that date.
[3] The time period is arbitrary. The idea is to provide sufficient lead time for the authorities to correct the conditions that might ultimately lead to a currency crisis.
[4] This could be the threshold for an indicator for which an increase makes it more likely that a crisis will occur. If smaller values raise the likelihood of a crisis (changes in the terms of trade, deviations of the real exchange rate, changes in reserves, foreign exchange exposure) the comparable threshold would be the 10th percentile.

Fig. 1. Exchange Market Pressure Index and Crisis Threshold



indicator setting and whether a crisis occurred, the result for that month is entered into one of the four cells in the following 2x2 contingency table (**Table 1**).[5]

Table 1. Example 2x2 Contingency Table

	Crisis within 24 months	**No crisis within 24 months**	**Row Totals**
Signal	A. true_crisis	B. false_no crisis	
No signal	C. false_crisis	D. true_no crisis	
Column Totals	24	152	176

Imagine that we have an indicator that emits a signal 24 months before a crisis, as well as in each of the next 23 months. This gives us 24 true signals for the crisis. That is, in each of the 24 months before a crisis, we answer affirmatively the question does a crisis occur at any time over the next 24 months? For this hypothetical indicator we would enter a count of 24 in the northwest cell of the contingency table, which we have labeled "A. true_crisis".

We also need to assess the accuracy of the indicator by answering another question. Absent a signal, does a crisis *not* occur over the next 24 months? If there is no signal and no crisis we enter a tally in the southeast cell of the table, which we have labeled "D. true_no crisis". If our hypothetical indicator were perfect, we would have a score of 24 in the northwest cell and a score of 152 in the southeast cell. There would be zeroes in the off-diagonal cells.

But indicators are not perfect. There will be instances when the indicator will signal a crisis, but nothing happens over the next 24 months. In this case the tally goes in the northeast cell, labeled "B. false_no crisis". And there will be instances when the indicator emits no signal and a crisis occurs, in which case the tally is entered in the southwest cell ("C. false_crisis").

We can begin assessing the quality of an indicator by calculating conditional probabilities with the cell counts in the contingency table. For example, given the occurrence of a crisis within the forecast horizon, one can calculate the percentage of time over which the indicator emitted a signal. In this case we are looking only at the "crisis" column of the contingency table to compute the probability (percentage) that a signal was emitted. This probability is given by A/(A+C), where the letters correspond to the first part of the label in each cell of the contingency table. The higher this probability is, the better. This only tells part of the story, however. We need to know how noisy the signal is. In particular, given that no crisis occurs over the forecast horizon, how often did the indicator emit a signal during the preceding 24 months? Looking at the "no crisis" column of the contingency table, we compute this by B/(B+D). The lower this probability is, the better.

[5] The example is for an indicator for which data through August 2002 are available. For indicators based on monetary data, the total number of observations will be 166, with 142 as the sum of the "no crisis" column. Also, for months in which a crisis is occurring, we do not tally results for the indicators, because we have little interest in whether an indicator is signaling that fact.

Forming the ratio of the first probability to the second probability yields a type of signal-to-noise (S/N) ratio. The larger the S/N ratio is, the better the indicator is at signaling a currency crisis. We rank our candidate indicators by the size of their S/N ratios (**Table 2**).[6] Consider the example of a perfect watchdog, who barks only when a thief is trying to enter the premises, but is silent otherwise. In this case, A/(A+C) = 100% and B/(B+D) = 0%. In the next block, there lives a dog that barks at everything: thieves, squirrels, cars passing in the street, etc. In this case, A(A+C) = 100% (the same as the perfect watchdog), but B/(B+D) = 100% also.

Table 2. Performance Measures of Indicators

	Probability of signal given crisis (1)	Probability of no signal given no crisis (2)	Signal-to-noise ratio (3)	Probability of crisis given signal (4)	Probability of crisis given signal − prob. of crisis (5)
Real exchange rate	63%	3%	23.8	79%	65%
Terms of trade	54%	3%	16.5	72%	59%
Foreign exchange exposure	29%	4%	7.4	54%	40%
Interest rate parity	38%	8%	4.8	43%	29%
Domestic credit/M2	33%	7%	4.7	44%	30%
Real interest rate	63%	14%	4.5	42%	28%
M2/international reserves	21%	17%	1.2	17%	3%
Public sector credit growth	13%	22%	0.6	9%	-6%
Public sector credit/domestic credit	8%	19%	0.4	7%	-8%
International reserves	4%	18%	0.2	4%	-10%
Domestic credit growth	4%	22%	0.2	3%	-11%
M2 multiplier	0%	23%	0.0	0%	-14%
Inflation	0%	20%	0.0	0%	-14%

Note: The values for each indicator in this table represent the maximum S/N ratio resulting from a grid search over the 10^{th} to 20^{th} or 80^{th} to 90^{th} percentiles, as appropriate.
(1) In terms of Table 1, A/(A+C).
(2) In terms of Table 1, B/(B +D).
(3) (1)/(2).
(4) In terms of Table 1, A/(A+B).
(5) The unconditional probability of a crisis is (A+C)/(A+B+C+D).

[6] The results in the table are the outcome of a grid search. To define a signal, we started with the 10^{th} percentile of the values of an indicator (where negative values of the indicator make a currency crisis more likely) or the 90^{th} percentile (for indicators where a positive value make the crisis more likely). We calculated the adjusted signal-to-noise ratio for each indicator. We then progressively lowered the thresholds by using the 11^{th} to 20^{th} percentiles (or 89^{th} to 80^{th} percentiles). The lower the threshold, the more signals would be generated, some of which would be true and some of which would be false. This gave us a range of signal-to-noise ratios for each indicator, from which we selected the largest.

Computing the S/N ratios for these two dogs lets us distinguish which dog is truly useful and which is the public nuisance. The S/N ratio for the perfect watchdog is undefined (essentially infinity because of a division by zero), whereas the S/N ratio for the public nuisance is 1.0. In assessing the quality of an indicator, then, we look for values above unity, the larger the better. By this criterion, we would eliminate 3 of the 4 domestic credit measures (the share of public sector credit in total domestic credit, domestic credit growth, and public sector credit growth), changes in the M2 multiplier, changes in international reserves, and inflation as credible indicators.

Indicators with the highest S/N ratios include deviations of the real exchange rate from trend, changes in the terms of trade, changes in the foreign exchange exposure of deposit money banks, deviations from interest rate parity, changes in domestic credit to M2, and the real interest rate. All of these indicators have S/N ratios greater than 4.0.

Another way to assess the quality of an indicator is to look at a related conditional probability, the probability of a crisis given a signal, and see how much greater this is than the unconditional probability of a crisis (Kaminsky, Lizondo, and Reinhart 1998). In other words, given that we have a signal from an indicator, how likely is it that a crisis will occur during the next 2 years? This is computed by using the values in the "signal" row of the contingency table to compute the probability A/(A+B). The results are presented in column (4) of Table 2.

By subtracting the unconditional probability of a crisis from this measure, we can see how much better the indicator is at predicting a crisis (last column of Table 2). The unconditional probability of a crisis is 24/176 = 0.14, not the 5.9% likelihood suggested by a crisis lasting 11 months during the 187 month period under consideration.[7] Note that a signal from the best indicator (deviations of the real exchange rate) is followed by a crisis within the next 24 months 79% of the time. This conveys significantly more information than does the unconditional probability alone. The terms of trade is also a powerful indicator by this criterion. A signal from the M2/reserves indicator, on the other hand, with a differential probability of 3%, provides little more information than does knowledge of the unconditional probability alone. The indicators with a negative differential probability correspond to the ones with a S/N ratio less than one, offering additional evidence that these indicators should be eliminated from an early warning system.

Based on the assessment of indicator quality in Table 2, our early warning system would contain the first 6 indicators in the table: real exchange rate, terms of trade, foreign exchange exposure, interest rate parity, domestic credit/M2, and the real interest rate. We can explore the performance of these indicators further by seeing how far in advance and for how long each indicator signaled a crisis. (**Table 3**).

The retained indicators emit significantly more signals in the 24 months prior to the crisis than do the indicators dropped from consideration (see last column of table). The real exchange rate

[7] The difference arises from the definition of the event whose likelihood we are evaluating. We are asking whether a crisis occurs anytime over a 24 month period following a signal; this includes a larger portion of our reference period than simply calculating the proportion of the reference period in which there was a crisis.

and the real interest rate issued the most signals and they did so 2 years in advance of the crisis. All of the retained indicators gave at least 12 months warning.

Table 3. Advance Warning and Persistence of Indicators

Indicator	No. months advance notice	No. signals prior to crisis
Included in early warning system:		
Real exchange rate	24	15
Terms of trade	13	13
Foreign exchange exposure	15	7
Interest rate parity	24	9
Domestic credit/M2	12	8
Real interest rate	24	15
Dropped indicators:		
M2/international reserves	22	5
Public sector credit growth	11	3
Public sector credit/domestic credit	11	2
International reserves	21	1
Domestic credit growth	10	1
M2 multiplier	0	0
Inflation	0	0

Performance of the Early Warning System

Further insight into the performance of the retained indicators can be gleaned by examining the pattern of the signals in the 2 years prior to the crisis beginning in July 2000 (**Table 4**). The real exchange rate signaled a crisis early and persistently for the first 15 months of the period, then stopped signaling for the 9 months immediately preceding the crisis. Deviations from interest rate parity exhibited the same pattern, although the signals did not last as long—which is why this is a weaker indicator than the real exchange rate. The terms of trade was silent at the beginning of the 24 month period, but 13 months before the crisis it began signaling and did not stop. The remaining 3 indicators flickered on and off throughout the period.

The behavior of these 3 indicators illustrates the difficulties facing the users of an early warning system: is the indicator signaling truly or is it emitting noise? For each month prior to the crisis we tabulate the number of indicators signaling together (last column of Table 4). Intuitively, we would tend to believe that a crisis was more likely if several indicators were signaling simultaneously and persistently. For the first year of the two-year period leading up to the crisis, 2 to 3 indicators were signaling simultaneously. For the first 8 months of the second year, 3 to 4 indicators were signaling simultaneously. The intensity of the warnings increased during this time, relative both to the preceding year and to the subsequent 4 months (after which the crisis occurred).

As a basis of comparison, we construct a similar table for the 24 months prior to the period considered in Table 4 and see how the indicators behaved individually and as a group during this tranquil period (**Table 5**). No signals were emitted in the first 6 months of this period. For the next 13 months either the interest rate parity or the real interest rate indicator were signaling. During the last 5 months of the period, between 2 and 3 indicators were signaling falsely.

Table 4. Performance of Selected Indicators in the 24 Months Before the Crisis

Months before crisis	Real exchange rate	Terms of trade	Foreign exchange exposure	Interest rate parity	Domestic credit/M2	Real interest rate	Total no. indicators signaling
24	1	0	0	1	0	1	3
23	1	0	0	1	0	1	3
22	1	0	0	1	0	1	3
21	1	0	0	1	0	0	2
20	1	0	0	1	0	0	2
19	1	0	0	1	0	0	2
18	1	0	0	1	0	0	2
17	1	0	0	1	0	0	2
16	1	0	0	1	0	0	2
15	1	0	1	0	0	1	3
14	1	0	1	0	0	1	3
13	1	1	0	0	0	1	3
12	1	1	1	0	1	0	4
11	1	1	1	0	1	0	4
10	1	1	1	0	1	0	4
9	0	1	1	0	1	1	4
8	0	1	0	0	1	1	3
7	0	1	1	0	1	1	4
6	0	1	0	0	1	1	3
5	0	1	0	0	1	1	3
4	0	1	0	0	0	1	2
3	0	1	0	0	0	1	2
2	0	1	0	0	0	1	2
1	0	1	0	0	0	1	2

Three points should be noted. First, during much of the tranquil period, the early warning system was essentially quiet. Second, the results emphasize the importance of not relying too heavily on signals from one indicator in concluding that a crisis is likely. Our results suggest that 3 or 4 indicators flashing simultaneously constitute strong advance notice that a crisis will occur. Third, the comparison highlights the arbitrariness of a 24 month look-ahead period. The last 3 months of the tranquil period resemble the first 3 months of the 2-year period before the crisis—3 indicators are signaling in each case.

Table 5. Performance of Selected Indicators During a 24 Month Tranquil Period

Months before	Real exchange rate	Terms of trade	Foreign exchange exposure	Interest rate parity	Domestic credit/M2	Real interest rate	Total no. indicators signaling
24	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
18	0	0	0	1	0	0	1
17	0	0	0	1	0	0	1
16	0	0	0	1	0	1	2
15	0	0	0	0	0	1	1
14	0	0	0	0	0	1	1
13	0	0	0	0	0	1	1
12	0	0	0	0	0	1	1
11	0	0	0	0	0	1	1
10	0	0	0	0	0	1	1
9	0	0	0	0	0	1	1
8	0	0	0	0	0	1	1
7	0	0	0	0	0	1	1
6	0	0	0	0	0	1	1
5	0	0	0	0	1	1	2
4	0	0	0	0	1	1	2
3	1	0	0	0	1	1	3
2	1	0	0	1	0	1	3
1	1	0	0	1	0	1	3

View from the Past: How the Early Warning System Would Have Performed Prior to the 2000 Crisis

We go back to the end of 1998, use the data available then to construct the EMP index and the indicators, and see from that perspective how the early warning system would have signaled the currency crisis that took place 19 months later. The results discussed above were based on a data set that included a currency crisis. By going back to a pre-crisis period, we can conduct a type of out-of-sample test of the system. It is not a true out-of-sample test because we used the entire sample to choose the best indicators and to discard the rest. Nevertheless, it conveys the flavor of what the looming currency crisis would have looked like to the users of an early warning system.

When we truncate the sample period, we change the variances of the index components. The EMP index values will be different than the full-sample values, which changes the mean and variance of the index, and therefore the threshold that defines a currency crisis. The critical

values applied to the indicators to determine if a signal is being sent are also different from their full-sample values. Thus, the status of an indicator at any particular date could potentially vary between the full and truncated sample. In practice, we expect the differences in the EMP index and the pattern of signals arising from these differences in variances to be small.[8]

A new EMP index, threshold value, and set of signals was constructed using data through 1998. We then constructed additional monthly values of the index and the signals for the remainder of the period, *holding constant the threshold value, variances of the component series, and the indicator critical values*.[9] The EMP index and crisis threshold based on the truncated sample start the crisis in June 2000 with a duration of 13 months; with the full sample values, the crisis began in July 2000 and lasted for 11 months. The results are summarized on a quarterly basis in Table 6.

Table 6. EMP Index Behavior and Signals Prior to 2000 Crisis

Date	EMP as % of critical value	% ch from prev. quarter	No. of signals	Real exchange rate	Terms of trade	For. exch. expo-sure	Interest rate parity	Dom. credit/ M2	Real interest rate
12/98	50%	-9%	2	1	0	0	1	0	0
03/99	48%	-2%	4	1	0	1	1	0	1
06/99	45%	-3%	4	1	1	1	0	0	1
09/99	47%	2%	5	1	1	1	0	1	1
12/99	75%	28%	4	0	1	1	0	1	1
03/00	85%	9%	2	0	1	0	0	0	1
06/00	112%	27%	2	0	1	0	0	0	1

Well before the index rises sharply in the fourth quarter of 1999, at least 4 and sometimes 5 indicators are signaling a crisis. As a matter of fact, even though the index continues rising over the next two quarters, the number of signals drops to 2. This emphasizes the role of the indicators in providing warning signals of a crisis to come. Merely tracking the behavior of the index itself is not sufficient. The signals are more numerous over a period in which the index itself is relatively quiet. However, the combination of 4 signals plus a sharp increase in the EMP index as of December 1999 could have provided a powerful signal that serious pressures were building in the market for foreign exchange.

[8] The biggest difference between the full and truncated samples was in the variance of nominal exchange rate changes. The truncated sample variance was 0.038, compared with the full sample variance of 0.079. This led to a greater weighting of exchange rate changes in the EMP index in the truncated sample.

[9] This was the most tractable approach operationally. The variances and critical values would change each time an observation was added, but the payoff from recomputing the index and the signals so frequently would be very small.

Conclusions

In this note, we developed an index of exchange market pressure for Ghana that combined the effects of exchange rate depreciation, changes in international reserves, and the interest rate on 91-day Treasury bills. A currency crisis occurs when the index exceeds a threshold value of 2 standard deviations above its mean. Over the period 1987-2002 we found one crisis with a duration of 11 months beginning in July 2000.

We then analyzed a set of candidate indicators to determine which ones, if any, gave persistent and early warnings of a crisis. We found 6 indicators that should be included in an early warning system: deviations of the real exchange rate from trend; changes in the terms of trade; changes in the foreign exchange exposure of the deposit money banks scaled by international reserves; deviations from interest rate parity; changes in the ratio of domestic credit to M2; and the real interest rate.

The system began warning of a crisis a full 24 months ahead. The intensity of the signals, measured as the number of indicators emitting signals simultaneously, grew stronger during a period beginning 15 months in advance of the crisis and lasting until 5 months prior to the crisis. At its best, 4 indicators were signaling simultaneously for a 6 month period beginning one year from the date of onset.

We then conducted a "what-if" scenario, whose premise was the existence of the early warning system at the end of 1998. Using the data available as of that date, we constructed the EMP index, computed the crisis threshold, and the signals from our set of leading indicators. We found that 4 to 5 of the indicators were simultaneously signaling a crisis throughout 1999, well before the EMP index began rising sharply in the last quarter of 1999. This would have given the authorities ample time to determine the source of the incipient pressure in the exchange market, and to take steps to avert the crisis.

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Appendix A. List of Variables Considered as Indicators

Variable	Description
Real exchange rate	Deviations from trend of the logarithm of the bilateral real exchange rate (cedis per US dollar)
Real interest rate	Nominal interest-equivalent rate on 91-day Government of Ghana Treasury bills deflated (in ratio form) by the year-on-year inflation rate
Interest rate parity	Deviations from parity using 3-month Treasury bill rates for Ghana and US; a positive deviation means that Ghanaian T bills earn a greater (exchange-adjusted) return than US T bills
International reserves	12-month percentage change
Terms of trade	Ratio of average of cocoa and gold prices to petroleum prices; 12-month percentage change
Foreign exchange exposure	Net foreign assets of deposit money banks (converted to US dollars) divided by international reserves; 12 month differences
M2 multiplier	12-month percentage change
M2/international reserves	M2 converted into US dollars; 12-month percentage change
Inflation	12-month percentage change in CPI
Domestic credit growth	12-month percentage change
Domestic credit/M2	12 month differences
Public sector credit growth	12-month percentage change
Public sector credit/domestic credit	12-month percentage change

Source: *International Financial Statistics*, IMF.